AN ENERGY SAVING SMART PEDESTRIAN LIGHTING SYSTEM WITH IoT

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ABSTRACT

A large quantity of electricity in many countries is consumed towards lighting up the streets. Most of the basic street lighting systems are switched ON/OFF at regular intervals of time. In this thesis, a system is proposed to develop an energy saving pedestrian light control system to reduce energy consumption. This is done by having an automatic system that detects human presence near the pedestrian path. Consequently, this system may save a large amount of electrical power as well as increase the lamp's lifetime and reduce pollution. The system works by keeping lamps on an off state at all night, except a few which will serve as guide lamps. When someone approaching the pedestrian path, an IR sensor sends a message to a microcontroller to turn the lamps ON. An Arduino microcontroller has been used as a controller for the project in addition to other components used for this system such as IR sensor, a current sensor, LDR sensor, RF wireless module, and ESP8266 module. In order to monitor the system at anytime and anywhere, the system is connected to the IoT cloud via Thingsboard using a WiFi network connection. The proposed system has been observed to reduce power consumption by 40-45 percent compared to conventional system.

ABSTRAK

Sebahagian besar penggunaan elektrik di banyak negara adalah bagi tujuan menyalakan lampu jalan. Kebanyakan sistem lampu jalan ini dihidupkan dan dimatikan pada selang masa yang tetap. Tesis ini mencadangkan pembangunkan sistem kawalan tenaga bagi lampu di laluan pejalan kaki untuk mengurangkan penggunaan tenaga. Ini dilaksanakan dengan penghasilan sebuah sistem automatik yang mampu mengesan kehadiran manusia di laluan pejalan kaki tersebut. Kesannya, sistem ini mampu menjimatkan penggunaan tenaga elektrik di samping memanjangkan jangka hayat lampu dan mengurangkan pencemaran. Sistem ini berfungsi dengan mematikan keseluruhan lampu jalan melainkan sebahagian kecil yang bertujuan sebagai lampu pemandu. Jika seseorang menghampiri laluan tersebut, penderia IR akan menghantar mesej kepada pengawal mikro bagi menghidupkan lampu di laluan tersebut. Pengawal mikro Arduino digunakan sebagai pengawal dismaping komponen lain seperti penderia IR, pengesan arus, penderia LDR, modul tanpa wayar RF dan modul ESP8266. Bagi membolehkan pemantauan pada bila-bila masa dan dari mana-mana tempat, sistem ini dihubungkan kepada Objek Rangkaian Internet melalui aplipkasi Thingsboard. Sistem yang dicadangkan ini didapati mampu mengurangkan penggunaan tenaga antara 40-45 peratus berbanding sistem konvensional.

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PC	-	Personal Computer
η	-	Learning rate IR
LDR	-	Light dependent resistor
RF	-	Radio Frequency
ESP	-	Wi-Fi microchip with full TCP/IP stack
ALS	-	Automatic lighting system
PLS	-	Pedestrian light sensor
LCS	-	Light control system
SOC	-	System on chip
TCP/IP	-	Transport control protocol /internet protocol

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The street or house lighting is one of the biggest energy consumption for a city. Researches has shown that the fluorescent lamps used in the world number to more than 300 billion lamps and the energy consumed by these lamps account to more than 40 percent of the total electricity usage [1, 2, 3]. In addition, these lamps produce more than 20 billion tons of carbon emission each year. Therefore, there is a pressing need to find a solution that would reduce the energy consumption due to lighting [1].

The current municipal street lighting has many problems. The downside of the past street light system is that it requires manual operation of the pathway light which consumes more electricity because, it depends on the personality of a person. In a crowded pathway and ones that are empty, ON and OFF time differ discernibly which is one of the significant hindrances of the present street light systems. Conventional street lighting systems which are turn ON during the night are without purpose because they are not being used all the time and the consequence is that a large amount of power is wasted meaninglessly [2]. This problem can be solved by using automatic lighting system.

At the present day, automatic lighting systems (ALS) have become more popular and have gained attention from many researchers and developers. Researchers have developed many algorithms to get an efficient and reliable energy saving system [13-18]. There are two approaches for energy efficient lighting. Firstly, the use of highly efficiency light sources, and the development of smart lighting techniques. An illustration of the latter is the thermal infrared sensing technique, often used for indoor lights that can be switched ON/OFF automatically when there is somebody/nobody present. On top of that, a lighting system can be made adaptive, such that the indoor

brightness can be maintained at a constant level taking into account the contribution of outdoor sunshine [3].

These systems can be connected to the internet through IOT cloud [4, 5]. This would allow the system to be more efficient and more reliable in detecting and monitoring fault. IOT is the network of physical devices that allows all devices to be connected to each other. IOT also allows remote sensing and control over the devices. It is an advanced automation and analytics system which uses artificial intelligence technology to deliver advanced and automated products and services. These system allow greater transparency, control, and good performance [6].

Pedestrian light sensor (PLS) algorithm is one of the most popular way to reduce power consumption in smart city or smart house. It consists of several sensors node that allow the transfer of information of the physical environment to electrical signal that can be analyses. This would enable the system to adjust the lighting brightness which would result is less electricity being consumed [7]. Each sensor node consists of infrared sensor (IR) that allow the detection of human movement, light sensor that detect luminosity, microcontroller that gives order according to the input from each sensor, and a transceiver system that allows connection and collaboration with many other sensor node. Furthermore, a radio transceiver would enable the system to send and receive data through a wireless medium in order to provide wireless local network [7]. There are several wireless system that allows the transfer of data. For example, ZigBee [8] allow transfer of information between point to point with less power consumption, less data rate and high transmission range of up to 1 Km. Wi-Fi allow transfer of information from node to cloud with higher power consumption, and higher data rate and transmission range of 100M [9].

This project aims of developing a prototype for pedestrian lighting system. The system consists of several sensor nodes. Each node contain IR sensor, current sensor, and Light Dependent Resistor (LDR) and RF transceiver RF24L01 module. The coordinator node have plus one module ESP8266 module. These system are connected to the internet through IOT cloud. The wireless system chosen is Wi-Fi to transfer the information from coordinator node to IOT and verse visa. The proposed system is expected to reduce power consumption by 35-40 percent compared to conventional system. In addition this system would be able to detect and monitor the fault such as broken lamp.

1.2 Problem statement

Excessive consumption of electrical energy is a general issue with many municipality due to many reasons. One of the reasons is lighting the street and pedestrian. It is very common to see the pedestrian light alight all night, which is a great waste of energy because some pedestrian paths are not in use all night. For example, after midnight there are not many people who want to walk on pedestrian way. This is the reason why power consumption is relatively high. In addition, street lighting and houses consume approximately 30-40 percent of the total electricity consumption of the world [10, 11, 12, 13].

The reliability of the lighting system is another issue, because the system needs to continuously monitor and detect broken lamps. The traditional system is unable to detect this problem and therefore make the system less reliable. Maintenance workers are needed to routinely check the condition of each lamp which means more money is needed to maintain the system. In addition, lake of power street lighting could contribute to higher number of crimes committed and this would result in unsafe roads.

In order to solve these problems is to developing a system that can reduce energy consumption and electricity wastage. By automation, in addition to having a smart monitoring system that can detect fault. This can be implemented using microcontroller equipped with sensors that can detect and communicate the status of the lighting system on hand.

1.3 Objectives of the study

The purpose of this project is as listed below:

(i) To design and develop a pedestrian lighting system using light control system (LCS) algorithm to reduce power consumption of pedestrian pathway light through developing prototype system.

(ii) To design a system that is able to detect lighting fault based on IOT technology.

(iii) To evaluate the performance of the system in term of energy consumption and reliability.

1.4 Scope of project

To fulfill the stated objectives, the scope of this project is as the following.

(i) This system are used several light nodes. Each node consists of three sensors (infrared sensor, LDR sensor and current sensor) and NRF24l01 transceiver module. IR sensor is used for human detection, LDR sensor is used for measuring light intensity and current sensor for measuring lamppost's current. NRF24l01 is used to establish communication link between the nodes.

(ii) Arduino Uno used for each node for the purpose of controlling all available sensors, using C++ software language to proses the signal.

(iii) Thingsboard IoT platform used for monitoring the pedestrian light system which include:

a) State of the lampposts (ON, OFF and broken).
b) Fault detection.
c) Energy would be consumes form the lamppost.

1.5 Thesis organization

1. The first chapter (INTRODUCTION) describes the aim, objectives and scope of the research as well as the structure of the thesis. The literature review is a critically written and comprehensive account of the published works on a topic by accredited scholars and researchers.
2. This third chapter (METHODOLOGY) explains in detail the samples, instruments, materials, procedures and data gathering methods used in the research.
3. (DATA ANALYSIS AND RESULTS) chapter explains the data analysis techniques and results through written text, figures, tables, and/or other means.
4. (DISCUSSION AND CONCLUSIONS) chapter, discusses the results and research findings by comparing them with the previous research work mentioned in the literature review chapter. Conclusions are drawn based on the research findings and their implications. Future works are also discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter deals with articles that are related to automatic street or pedestrian light system. Numerous researches and source have been conducted previously, hence, following from there, some details on this project have been established and a brief knowledge could be understood regarding the project. This chapter presents the theoretical background of the research as well as the review of previous studies that have been conducted.

2.2 Theoretical background

This section provides the background and theory on IoT and pedestrian light system.

2.2.1 Internet of Things (IoT)

Internet of things (IoT) is a network of physical devices connected to each other which exchanges data and information via sensors and actuators. In other words, IoT is a collection of devices linked to the internet to make our life much easier. The 'things' here refer to devices such as cameras, chips sensors or other physical devices. The IoT allow the devices to be sensed and remotely controlled through the network infrastructure, making opportunities for more instantaneous integration between the physical world and the computer-based systems, which then leads to more accurate, efficient and inexpensive system [14] [15].

The technology becomes an occurrence of the more familiar category of cyber-physical systems when IoT is added on with actuators and sensors. This consists of

technologies such as intelligent transportation, smart pedestrian light system, smart cities, smart grids as well as smart buildings. Each thing possesses a computing system which is uniquely traceable and may integrate within the standing Internet infrastructure. It is estimated that by 2020, IoT will connect around 50 billion things [14, 15].

2.2.2 Cloud computing

Cloud computing is a type of Internet-based computing which authorizes processing and shared data to computers and other electronic devices upon request. It is a method used for activating ubiquitous, on-request access to a shared gathering of formable computing assets. Users and enterprises use cloud computing and storage solutions to process and store data in either their own servers or third-party data centers [16] [17].

The internet and central remote servers for handling data and applications are used in cloud computing. In the case of data handling, users are able to access data from any network terminal. In addition, cloud competing allow for resources available on each terminal to be pooled and used to perform a complex task. Efficient computing by centralizing processing, data storage and bandwidth can be achieved by using this technology [16] [17].

2.3 Application of IoT

IoT assists with the development progress of myriad industry-oriented and user-specific IoT implementation. Although networks and devices supply physical connectivity, IoT applications allow human-to-device and device-to-device connections in a robust and reliable manner [18] [19]. There are many applications based on IOT and the most common eight are:

- Smart Cities.
- Smart Home.
- Wearable gadgets.
- Connect cars.
- Industries.
- Agriculture.

- Energy.

2.3.1 Smart cities

Some features of smart Cities are security and environment monitoring, smart pedestrian light system, water distribution, smart surveillance, energy management and automated transport management. This work will focused on the implementation of smart pedestrian light system that could contribute to a more efficient consumption.

2.4 Types of pedestrian light system

Pedestrian light systems are mostly divided into two types. Conventional pedestrian light system and automatic pedestrian light systems. In the conventional light system, the lighting system is turned on and continue to do so until someone comes and turned it off. In automatic pedestrian light system, the process is different as the light is turned ON/OFF automatically based on sensors that have been put in places to monitor the environment. The main purpose of this system is to reduce energy consumption and save electricity. Examples of automatic pedestrian and street light system can be found in [20] [21] [22].

2.4.1 Smart solar LED Street light

An energy efficient, smart solar street light system using Arduino microcontroller was developed by Bhairi (2017). This system comes with energy efficient smart pedestrian light system for energy conservation in existing streetlights in both rural and urban area. The system consists of motion sensor, LED luminaire, Arduino, LED driver, light sensor, PV panel and charge controller. The smart streetlight is basically controlled based on day/night time as well as the amount of traffic on the road [23]. The system is programmed in such a way that it automatically turns OFF during daylight and only operates at night, during heavy rain or even bad weathers. Apart from that, an additional problem is the usage of traditional street lamps such as sodium vapor, Incandescent, metal halide and fluorescent lamps which consumes way more power in comparison to the new advanced led Lights. Upon utilizing automatically controlled,

self-powered as well as effective solar LED street light, the street lights can be operated free of cost. Figure 2.1 shows the system of the smart system.

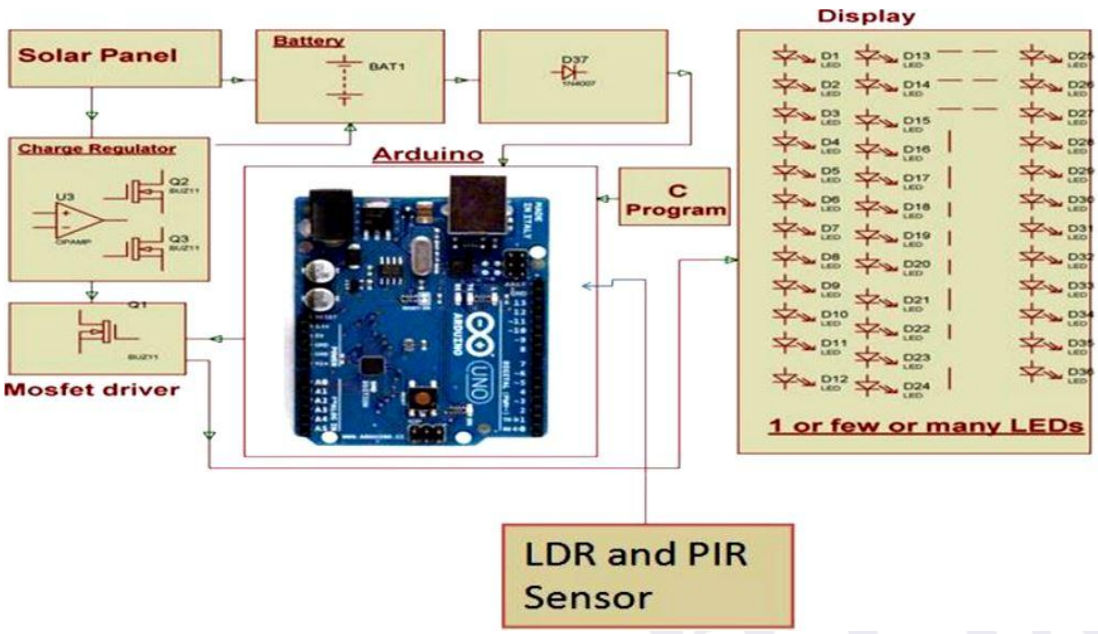

Figure 2.1: Block diagram of smart solar LED street light [23]

During day time, solar panel generates electricity which is then stored in the battery. From dusk to dawn time, light sensor provides command to Arduino controller. To switched ON the LED at 30% of the maximum intensity when there is no motion detected underneath the streetlight. Motion sensor activates and provides command to Arduino to gradually increase the brightness to 100% if a person or vehicle passes near the streetlight. The light intensity will be reduced back to 30 % when there is no motion detected after a period of time. During the day, the system will normally be turned off except during severe weather condition that require street illumination. During the day, the battery will be recharged using the solar panel. Figure 2.2 shows flowchart of the smart solar street light.

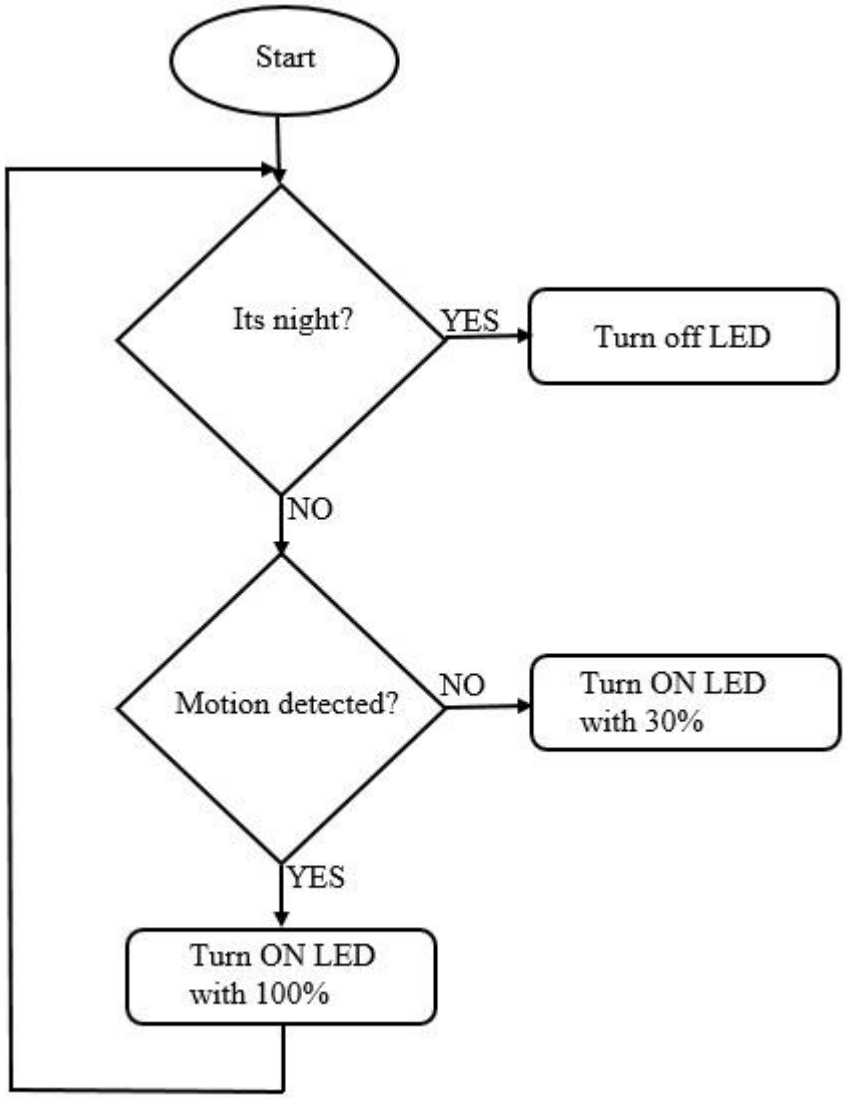

Figure 2.2: Flowchart of the smart solar LED street light [23]

2.4.2 Intelligent pedestrian light system

An intelligent solar street light system based LDR sensor was developed by Mamta Pandey (2015). The main aim for this type of street light system is saving power and energy which is a crucial factor in this system. The author proved that most countries these days are familiar with the regular street light system which unfortunately is not environmental and budget friendly. Hence, in this work, LED lights are selected over conventional lights since they do not radiate any CO2, and are much beneficial in comparison to the other lights and also the ability in control the lighting intensity [24]. Since power saving is the primary intention here, solar energy is utilized as the power

source to the battery. This way of power supply is preferred due to being able of save loads of energy since the energy comes naturally from the sunlight, which in turn is eco-friendly enough. Also, note that solar panels are utilized together with DC batteries [24]. Sufficient energy to switch ON the street light is provided since the battery gets charged from the solar panel. LDR is utilized to switch ON the light when it is night and switch OFF the light when it is day time automatically which reduces the manual effort.

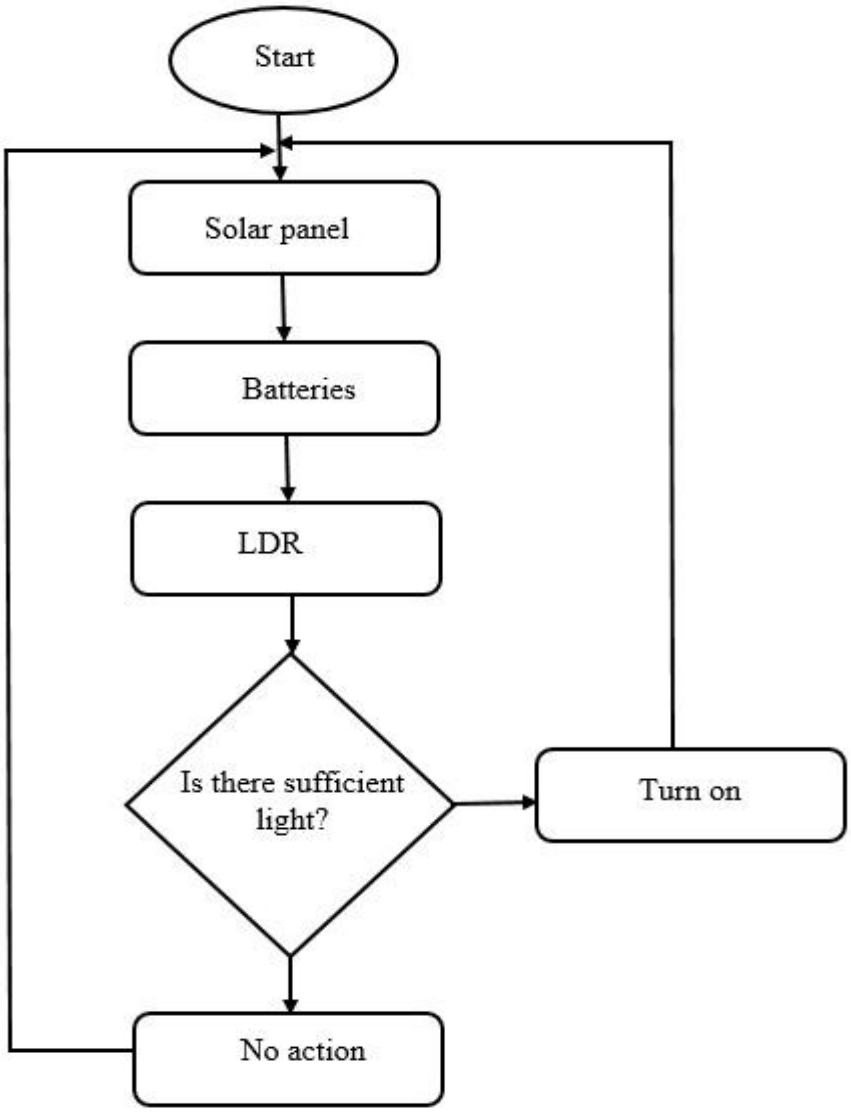

Figure 2.3: Intelligent pedestrian light system [24]

By applying this street light system approach, approximately 80-90\% of the energy could be saved, hence, solar energy is preferred since it is the most important and renewable source of energy [7], which aids in enhancing the energy saving. Figure 2.3 illustrates the block diagram of the solar street light system which explains that the

solar panels charged using batteries are the primary power source for this system [7]. The light then switches ON and OFF automatically using LDR. Here, the LDR determines if it is day time or night time and switches light ON or OFF the accordingly.

2.5 Pedestrian detection method

There are many types and ways to detect obstacle and object available these days. Each type uses specific type of sensor which include Ultrasonic sensor, IR sensor, and photoelectric sensor. In addition, image processing technique and also use to detect human presence and movement.

2.5.1 LDR and IR sensor detection

This work developed an automatic street light system using both light sensor and IR sensors. In this work, the light sensor detects the light intensity while the IR sensor is used to detect human presence. Microcontroller is used to determine whether to turn the light ON/OFF. In this system, street light will be turned on only when there is low intensity and human presence is detected [25]. Figure 2.4 illustrate a block diagram of the LDR and IR sensor detection method.

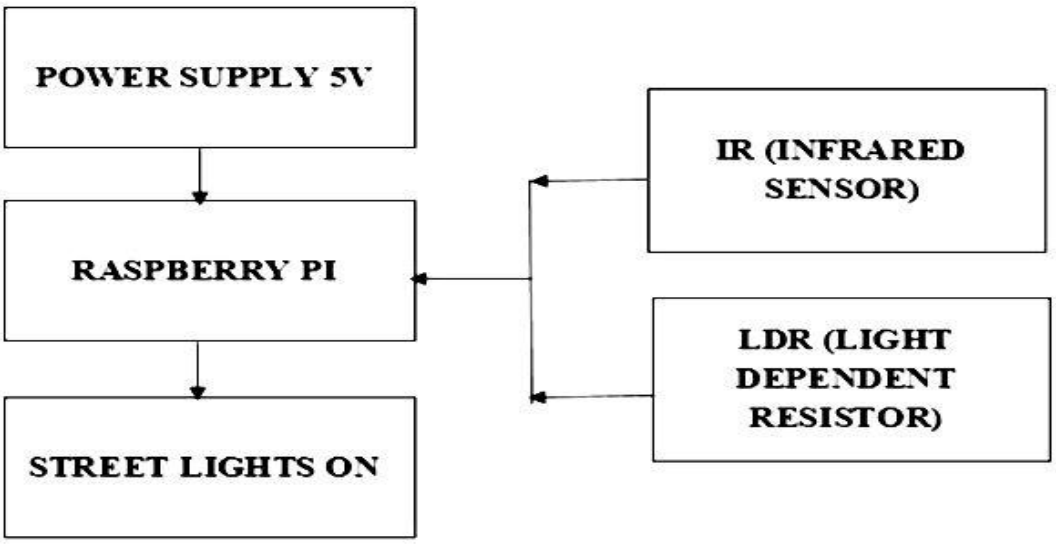

Figure 2.4: Block diagram of Automatic Street lights [25]

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